The Secretary also exhibited a photograph of a female Giraffe captured in the West Soudan, east of Timbuctoo, showing a general resemblance with *Giraffa camelopardalis typica*.

Dr. F. A. Bather, M.A., F.Z.S., exhibited a fossil Echinoid, *Scutellina patella*, from the Eocene? (Barwonian) of Nelson, Glenelg River, Victoria, Australia, showing a marsupium for the young, as described by T. S. Hall (Proc. Roy. Soc. Victoria, n. s. xx. p. 140, 1908).

The following papers were read:—

1. The Ectoparasites of the Red Grouse (*Lagopus scoticus*).

By A. E. Shipley, M.A., Hon.D.Sc., F.R.S., F.Z.S., Fellow and Tutor of Christ's College, Cambridge, and Reader in Zoology in the University.

[Received November 28, 1908.]

(Plates XXXV.–XLVII.*)

I have made a careful examination of all the animals I can find recorded both from the outside and from the inside of the body of the grouse, with the exception of the blood parasites *Leucocytozoon lovati* Seligm. & Samb.†, the Protozoa found by Dr. Fantham, and the Microfilaria described by Sambon. Besides the Protozoa found by Sambon, Dr. Fantham has found a species of Spirochæte in the blood prepared from smears taken from the heart and liver. Probably this is a new species, as it is somewhat short and thick. It was only seen on two occasions. A second Spirochæte was found in the intestine. It was seen alive and was not numerous. It is possibly the so-called *Trypanosoma eberthi* (Kent). Oocysts of *Coccidium avium* are common in the intestine and rectum. Gregarine spores, probably of *Monocystis*, are sometimes seen in the intestine; *Monocystis* spores having been recorded by Pfeiffer from the intestines of birds. A Hæmosporidian occurs in the erythrocytes, but was seen only in the younger stages. They are rare. An *Amœba* is found both in the rectal contents and in the droppings.

The animals which live *within* the grouse constitute the Entozoa or Entoparasites, those that live on the body form the Ectozoa or Ectoparasites, and with these latter this paper deals.

From the point of view of the Grouse Disease Inquiry the attention paid to the ectoparasites may seem superfluous, but many of the internal parasites and all the tape-worms pass through a second host. For example, the tape-worms which live in the alimentary canal of the grouse pass their younger or

* For explanation of the Plates, see p. 333.

† 'The Lancet,' 21 September, 1907, p. 829.

larval stages in the body of some lower animal. This lower animal, presumably an insect or a mollusc or a spider, must be eaten by a grouse and the larval tape-worm must be set free before the latter can grow up into the adult tape-worm which we find in the intestine of the grouse. In searching for this second host it was natural to begin with the ectoparasites, which one would imagine were continually being snapped up by the bird. We have, however, up till now completely failed to find any cestode-larvæ in the grouse-fly or in the numerous "biting-lice" or "bird-lice" (Mallophaga) which abound on the skin and amongst the feathers of the grouse; and, what is still more significant and still more remarkable, we have, in the hundreds of crop-contents which we have examined, never found one of these insects in the grouse's food.

This report is based in the main on my own observations, but some of the facts recorded were first observed by Dr. E. A. Wilson, and some by Mr. J. C. F. Fryer, of Caius College, Cambridge. In fact, in looking back over the work I find it difficult to disentangle the precise share each of us had in it. One thing, however, is clear. I am indebted to Dr. Wilson for a very large proportion of the drawings which have been reproduced in the Plates at the end of this paper, and I am also indebted to him for lightening many pleasant hours spent, not on the open, breezy heather of the Scottish moors, but in the stuffy laboratory we were wont to improvise in the back premises of many a Scottish inn.

To Mr. Edwin Wilson, of Cambridge, a word of thanks is also due for the accuracy and skill with which he has depicted the Grouse-fly and the Grouse-flea.

ECTOPARASITES.

INSECTA.

A. Mallophaga.—Bird-lice or Biting-lice.

(i.) Fam. **Philopteridæ.**

I.—*Goniodes tetraonis* Denny.

In his 'Monographia Anoplurorum Britanniæ,' Denny* describes and figures this species, which he calls the "Louse of the Black and Red Grouse." He states that it is "common upon both the Black and Red Grouse" (*Lagopus tetrix* and *L. scoticus*). "Upon the Willow or Hazel Grouse (*Lagopus saliceti*) I find a similar but distinct species, rather broader in the abdomen, and of much darker colour." Denny describes several species of the same genus which infest other game-birds.

* Published by H. G. Bohn, London, 1842, p. 161, pl. xiii. fig. 3.

Giebel * gives the name *Goniodes heteroceros* Nitzsch as a synonym of *G. tetraonis*, and in his large monograph on 'Les Pédiculines,' Piaget † uses the former name without any reference to Denny's. The name *G. heteroceros* also appears in Giebel's article ‡ on the Epizoa of the Halle Museum, published in 1866, but only the name. In his article on "Parasiten" in von Middendorf's 'Reise in den Aussersten Norden und Osten Sibiriens,' Grube attributes certain bird-lice taken from *Lagopus albus*, the Willow Grouse, and from *Lagopus alpinus*, the Ptarmigan, to the species *Goniodes tetraonis* Denny; but Piaget points out certain differences, and seems to consider that a new species might have been described from these specimens.

Andrew Murray, in his book on 'Economic Entomology' §, writing of *Goniodes tetraonis*, says:—"This is the insect which sometimes, especially in the bad seasons, does so much harm to the young grouse when they are feeble and unhealthy."

It is the commonest of the insects which infest the skin of grouse, crawling about amongst the base of the feathers and on the vane of the feathers themselves. It occurs more commonly than *Nirmus cameratus*, which is often associated with it. It is comparatively rare to find a bird free from these "biting-lice," but perhaps 10 per cent. is about a fair estimate of the number of uninfested grouse. The number on each bird is to some extent an inverse measure of their health. Careful search will discover but two or three on a healthy grouse, but on a "piner" hundreds may be met with. This is not, however, the case with birds that die quickly of acute disease.

Goniodes tetraonis is usually found on the smaller feathers, crawling about halfway between their insertion and the tip of their vanes. When disturbed they hurry away into the brushwood of the small feathers, like small deer seeking cover, and they are by no means so easy to catch as one would at first think. They eat the finer barbules of the feathers, which, accumulating in the crop, gives the dark curved marking in their rather transparent bodies. On this meagre and arid diet they seem to flourish, actively produce young, and pass through several ecdyses.

The naked-eye colour of *Goniodes* is a yellowish brown. Under the microscope the body appears rather transparent, but wherever there is chitin this is of a yellowish to chestnut-brown colour according to the thickness. The crop, which is full of minute fragments of the finest barbules of the feathers, presents a blackish sac-like appearance, running obliquely across the middle line of the abdomen; a somewhat parallel but much smaller black tube represents possibly the rectum (Pls. XL. & XLI. figs. 12 & 16). In a few cases the œsophagus and crop presented a red appearance, this being probably due to hæmoglobin from the blood of the grouse.

* 'Insecta Epizoa,' Leipzig, 1874.
† Leiden, 1880.
‡ Zeitsch. f. ges. Naturwiss. xxviii. 1866, p. 387.
§ Chapman & Hall, London, 1877.

The body is, on the whole, flattened—especially is this the case with the head and abdomen. The thorax, as Snodgrass* points out in *Menopon persignatum*, appears to be triangular in cross-section.

The Head.—The head is shaped somewhat like the semicircular knives used for cutting cheese. The head of the female is somewhat broader and shorter than that of the male, and is produced at the posterior-lateral region into a much more prominent angle. In both male and female the angle bears a spine and a long hair. The anterior rim of the head is bounded by a thick rim of chitin, beneath which is a layer of granular protoplasm with a few nuclei, the hypodermis. At intervals the chitin is pierced by narrow channels, into which the hypodermis extends, and the chitin bears at the outer end of each of these channels a short hair (Pl. XXXVI. fig. 4). From the inner surface of this rounded anterior edge of the head a number of muscle-fibres pass radially inwards to a structure which has been called the upper lip, and which will be described later under this name. Just in front of the recess from which the antennæ arise, the anterior thickened chitinous rim curves to an end, being bent in and then out to form a short apodeme of which the inner end acts as the basis of articulation of the anterior limb of the stout mandibles (Pls. XXXVI. & XXXVII. figs. 4 & 6). The socket of the antennæ is also provided with a thickened chitinous skeleton, and across the base of the head, separating it from the prothorax, is a thickened plate which presents in profile the appearance of a bow; the rest of the head is enclosed in thin yellow chitin. The appendages of the head will be described later, together with those of the body.

There is no neck, but the first segment of the prothorax is only about one-half the width of the head. The mesonotum is fused with the metanotum and the thorax appears to have but two segments. There is, again, no waist or constriction between the thorax and the abdomen, but the segments from the first thoracic to the second or third abdominal gradually and uniformly widen, and then as uniformly diminish in width until the last. The separation of the first thoracic segment from the second is marked by a stout chitinous rim both dorsally and ventrally—this is, however, only found in this region; the rest of the segments are soft and not chitinized in the tergal and sternal regions, but the pleura are protected by well-marked chitinous shields, which, however, extend but a very short way dorsally and ventrally (Pl. XXXV. figs. 1, 2 & 3). In *Nirmus*, however, the lateral plates are more extended.

According to Sharp† the Mallophaga have from 8 to 9 abdominal segments, and according to Railliet‡ the family in which he places *Goniodes* has 9; but he remarks that the last

* Pap. Calif. Ac. vi. 1899, p. 145.
† Cambridge Natural History, vol. v. Insects, i. London, 1895.
‡ 'Traité de Zoologie Médicale et Agricole.' 2nd Edn., Paris, 1895.

two are sometimes completely fused, so that we only find 8 visible segments.

There are certainly only 8 visible in *Goniodes*, although *Nirmus* has 9 complete segments. The last visible segment in the female is a slightly bilobed plate bearing no hairs; the anus opens just below it. In the male the plate is not bilobed; it is stouter and bears a number of backwardly projecting hairs. Each segment, except the last in the female, bears a number of hairs; the arrangement of these is shown in the figures 1, 2, & 3, Plate XXXV.

The appendages are as follows:—

I. The eyes.—Each eye is formed of a little aggregation of pigmented cells, the whole somewhat cup-shaped, and of an almost spherical transparent thickening of the cuticle, the lens. The eyes are situated close behind the thickened cavity from which the antennæ arise (Pls. XXXV. & XXXVI. figs. 1, 2, 3, & 4).

II. The antennæ.—These arise from a deep hollow the chitinized walls of which are much thickened. The cavity practically conceals the proximal joint, which is broader than long; the second joint is the longest and is almost twice as long as its broadest part; the third, fourth, and fifth segments uniformly diminish in size, and the fifth or last bears at its end a number of bristles. The male is readily distinguished from the female by the fact that the third joint is produced into an inwardly directed process very like a thumb, and this gives the antennæ a biramous appearance (Pls. XXXV. & XXXVI. figs. 1 & 4).

The next three pairs of appendages are modified as mouth-parts, and in describing them we propose to mention certain median structures also connected with the mouth.

The most remarkable feature of the under surface of the head of a *Goniodes* is a white cushiony area with the outline of a stout sausage, sometimes described as the "upper lip" or "labrum." It is bounded anteriorly by a ridge of chitin which takes its origin on each side from the inner face of the strong apodeme already mentioned. This cushion is covered with a multitude of rugosities, giving it the appearance of the skin of a dog-fish. There is always a more or less well-marked crease or groove across the long axis of the cushion, and the part posterior to the crease is supported by two longitudinal bars of chitin just as the double banners Temperance reformers carry in their processions are supported by the poles (Pl. XXXVI. fig. 5).

If one be watching the living *Goniodes* lying on its back on a slide, this cushion will be seen from time to time to swell up and scrape along the under surface of the cover-slip. Then it subsides again, possibly being pulled back by the numerous muscle-fibres which pass back from the anterior end of the head, and which appear to be inserted into the inner surface of the cushion. Along the posterior edge of the cushion is a small mobile membrane or lip which bears a moustache of eight hairs, shorter in

the centre, but increasing in length as one passes outward (Pl. XXXVI. fig. 5). This lip is frequently drawn down over the tips of the mandibles.

The only function one can suggest for the upper lip is that it acts as a scraping organ and it may be of use if the animal ever eats the epidermis of its host.

III. The mandibles.—These are by far the most powerful of the mouth-parts and are very strongly chitinized. The right and left mandibles are not exact images of one another, as the tip of one always closes outside the tip of the other, and thus there is a slight differentiation at the apex, which is so strongly chitinized as to be almost black. Each mandible is somewhat triangular in shape, the apex forming the tip. The articulation is very complex (Pl. XXXVII. fig. 6) and is mainly with the inner end of the powerful apodeme which runs in just in front of the base of the mandibles. A very powerful muscle runs into the external posterior angle of each mandible, the so-called condyle, and serves to bring it into biting contact with the other. The sharp shearing-edge of the mandible is admirably adapted for cutting off the barbules of the feathers which form the food of the biting-lice.

IV. The first pair of maxillæ.—These are very difficult to see in the living animal and are best observed when in movement. We agree with Grosse* in describing them as lobes without any traces of palps. They are rounded and bear certain setæ on them. When in motion they are shot up and pulled down between the mandibles and the labium or fused second maxillæ; sometimes both are moved forward at once, sometimes they move alternately (Pl. XXXVII. fig. 7).

V. The second pair of maxillæ.—These have fused together and form a labium of a very simple kind. There is a median plate or mentum in which we found no transverse furrow. This plate bears anteriorly a pair of one-jointed processes ending in a few short stiff bristles. These are called by Grosse the paraglossæ, but, as there are a pair of minute one-jointed processes internal to these, it may be that they represent the palps. Whichever they are, they are very mobile and are constantly being divaricated into a position at right angles to the normal and then suddenly brought back again. They are obviously of use in bringing food to the mouth. The more median processes as well as the palps bear hairs. They are figured on Pls. XXXVI. & XXXVII. figs. 5 & 7.

A median structure which we think may represent the hypopharynx is the lyriform organ, or the "œsophageal sclerite" of Kellogg. This median piece is strongly chitinized, deep brown in colour, and consequently conspicuous; it seems to lie about in the same level with the first maxillæ, except when they are

* Zeitschr. wiss. Zool. xlii. 1885, p. 537.

protruded, when it lies behind them. A muscle on each side of the œsophagus runs from the anterior angle of the sclerite to the dorsal side of the head and brings about the movement of the organ. Kellogg has described in certain species a pair of oval glands which lie ventral to the sclerite and the ducts of which unite and open by a common duct into the median groove of the thickening. These glands are very conspicuous in *Goniodes*, and are shown in several of our figures. Their function is unknown. Their ducts are cross-barred like a trachea. The whole sclerite is conspicuous and shines through as a somewhat **V**- or **U**-shaped dark area, visible from above. As Kellogg points out, a similar apparatus exists in the Psocidæ (Pls. XXXV., XXXVI., & XXXVII. figs. 3, 5, & 7). Two salivary glands on each side of the œsophagus have been described in many genera of Mallophaga. The ducts of all four unite and open into the pharynx by a common duct.

The second maxillæ are so minute and feeble that we found it impossible to dissect them out even from macerated specimens.

VI. The prothoracic legs.—These pair of appendages are turned forward and their ends normally lie underneath the mouth. They doubtless take some part in feeding. Their inner ends are approximated, so that the sternum here is but little more than a line. Snodgrass* records that the prothoracic legs do not move synchronously with either of the others or with each other. One often moves backward as the other moves forward, and he holds that they serve to guide the body. He thinks they serve to pull the body up the feather, the prothoracic legs pulling whilst the other legs push, like a man climbing a rope.

VII. The mesothoracic legs.—These are larger than the preceding and are directed backwards; their bases are further apart. The details are shown in Pl. XXXIX. fig. 10. All the legs end in claws and bear a well-marked pulvillus.

VIII. The metathoracic legs.—These are still larger and, like the preceding, are directed backwards; the sternum between their bases is rather wider. The right and left mesothoracic legs move forward simultaneously and backward simultaneously, and so do the right and left metathoracic legs; but when the mesothoracic legs move forward the metathoracic legs move backwards, and *vice versâ*.

In their general structure there is little beyond size in which the legs differ. Each consists of a coxa firmly applied to the ventral surface of the thorax; it is a broad, short piece, wide distally. The second article is a small trochanter which joins the hinder end of the wide coxa and seems to be almost part of the femur, but there is a marked thinning of the cuticle between it and the femur and a clear joint.

The femur with the trochanter and the next article or tibia

* *Loc. cit.* p. 152.

are of about equal length, but the tibia is not so stout; distally it bears a pair of stout bristles, hardly movable, against which the tarsal claws work. There are other bristles on the tibia, and numerous hairs on all the articles. The tibia bears a single-jointed tarsus which carries a pair of very mobile claws. These claws are constantly being depressed, usually one at a time, and rub against the tibial bristles. The tarsus also carries numerous knobs, and between the base of the claws a pulvillus may be seen; this in some cases is retracted.

The female has no external organs of reproduction, but on the seventh segment of the male there are situated ventrally a couple of complicated gonapophyses which presumably are modified abdominal appendages. These are figured on Pl. XXXVIII. fig. 9, which gives an adequate idea of their complexity.

Respiratory System.

The tracheal system of *Goniodes* opens on the exterior by seven pairs of stigmata. There may possibly have been more, but we could not detect them. The most anterior is the largest; it is situated close behind the first pair of legs and is very difficult to see. Snodgrass * has described one in a similar position in *Menopon titan*. From it a trachea passes inwards and gives off a twig to the second leg. Further on it divides, one stout branch running anteriorly into the head, where it divides into two, each splitting up into innumerable small branchlets supplying the organs in the head. From the main trachea the second branch passes backward, giving off a twig to the third pair of legs, and then runs backward through the abdomen as a main longitudinal trunk (Pl. XXXIX. fig. 11).

The abdominal stigmata are twelve in number, there being a pair on the second to the seventh segment, both included. They lie on little eminences like a tee in a teeing-ground, situated about one-sixth of the body breadth from the edge, and from each is given off a short trachea which soon splits into two branches. Of these the posterior splits up into innumerable fine twigs, which supply the various organs of the segment, and the anterior runs almost straight into the longitudinal trunk, thus placing the system connected with one stigma in communication with all the others on the same sides of the body. By this means, if one stigma be blocked the organs it supplies are not deprived of air, but receive it from another system. The smaller tubes on each side pass across the middle line and seem to place the right and left systems in communication. In *Menopon titan*, according to Snodgrass, the right and left systems communicate by means of a large transverse trunk in the fourth abdominal segment.

The spiral thickenings are well marked.

* *Loc. cit.*

The Alimentary Canal.

Grosse has described just within the mouth a dorsal and a ventral piece of a "schlundskelet." Unless the lyriform organ, or "œsophageal sclerite," represents the ventral piece, this structure is not evident except in sections.

The œsophagus is a simple tube with muscular walls which traverses the posterior part of the head and the thorax (Pl. XL. fig. 12). Soon after it reaches the abdomen it gives off a blind pouch or crop, which is always choked with feathers and forms the conspicuous black patch which shines through the wall of the abdomen. The walls are very muscular, both longitudinal and circular muscle-fibres being conspicuous. It usually lies near the middle line, but slightly obliquely, and pointing posteriorly to the right. Behind the point where the crop is given off the stomach or chylific ventricle passes backward, lying to the right of the crop. At the posterior end of this the four Malpighian tubules arise, and then there follows a short intestine in which usually masses of undigested feather-fragments are to be seen. The intestine is short and ends in a ring of six almost spherical (? glandular) bodies (Pl. XL. fig. 12). Each of these seems to consist of a single gigantic cell, and the whole is very richly supplied with tracheæ. These bodies closely resemble similar structures found in the rectum of many Diptera, *e. g.*, the blow-fly and the mosquito. Behind them there is a short rectum, which ends in an anus situated beneath the terminal plate. Numerous muscles run from the body-walls of the last two segments to be inserted into the rectum and doubtless act as divaricators.

The food consists of feather-barbules; a sample of it taken from the crop is shown in Pl. XL. fig. 13.

The Excretory System.

This system consists of (*a*) the Malpighian tubules, and (*b*) the Fat-body, in which nitrogenous waste matter is often stored away. The Malpighian vessels are four in number; they arise at the anterior end of the intestine, and near the base each swells into an oval vesicle (Pl. XL. fig. 12). The tubules are long, as long almost as the body, and are coiled away amongst the viscera.

The fat-body is very definitely arranged, there being paired pouches of it at the sides of each segment (Pl. XLI. fig. 16). In the cavity of these pouches are five collections of oval structures, which may be the five pairs of ovarian tubules, showing the ova, but somewhat similar structures occur, in equal numbers, in the male abdomen.

Nervous System.

We have not made a detailed examination of the nervous system, but may remark that it consists of a brain and a large infra-œsophageal ganglion in the head and of three ganglia in the thoracic segments. The last of these is the largest, and it supplies nerves to the organs of the abdomen.

Circulatory System.

This, again, we have not examined, but Wedl * and Kramer † have seen and described the hearts of several species. They seem to conform to the usual insect type, but the number of chambers is small, Wedl says only one in *Menopon pallidum*, situated in the last but one abdominal segment.

Reproductive Organs.

We have not investigated this system of organs in any detail, but it may be mentioned that in the Ischnocera, the subdivision of the Mallophaga to which *Goniodes* and *Nirmus* belong, there are four testes, the two on each side being united by a common vas deferens, which leads into a vesicula seminalis, which, though bilobed, is usually unpaired; from this an ejaculatory duct leads to a retractile penis. The extreme complexity of the external male organs is shown in fig. 9, Pl. XXXVIII. Morphologically there is an invagination of the body-wall of the last abdominal segment to form the genital cavity, and the various plates and bars which are seen in the drawing are chitinous thickenings in the walls of the invagination. In the centre of the genital cavity lies the penis, which is strengthened by chitinous rods and bars, and is capable of being protruded and retracted by a complicated system of muscles. In the male the anus has been involved in the invagination and comes to open dorsally into the genital cavity. This is not the case in the female, where the invagination is not close to the posterior end, but is formed by an invagination of the eighth abdominal segment. The vagina opens anteriorly and dorsally into this chamber, and passes into a long coiled oviduct which splits into two collecting-ducts, and these terminate in five ovaries on each side of the body. The ovaries dwindle out anteriorly, and their thread-like forward ends unite into a common termination.

An excellent comparative account of the reproductive organs of the group is given in Snodgrass's already-mentioned paper, and Gross ‡ has written an account of the histology of the ovary, which he finds strikingly like that of the Pediculidæ.

* SB. Ak. Wien, xvii.
† Zeitschr. wiss. Zool. xix. 1869, p. 452.
‡ Zool. Jahrb. Anat. xxii. 1905, p. 347.

The Eggs.

The eggs are very beautiful objects; in badly infested grouse they may be numerous, but as a rule they were none too easy to find. Usually they occur in small groups attached to the base of the after-plume and between it and the shaft of the plume. The specimen figured was on one of the feathers from the flank.

The eggs are elongated, some three to four times as long as they are broad. They are fixed by some adhesive secretion at the end corresponding to the posterior end of the contained embryo. At the other end is a well-marked cap or operculum which always points to the free end of the feather. The beauty of the reticulated egg-case is shown best in the genus *Menopon*, and we figure one, which we take to be the egg of *Menopon pallescens* Nitzsch, found on the feathers of a partridge. Under the pressure of a cover-slip the egg-case gradually ruptured along a circular line below the well-marked thickened edge or rim of the operculum. The contained egg then began to emerge, carrying the operculum as a sort of cap, the resemblance to which was emphasised by the long process which stands out like a feather borne on the apex. The eggs of *Goniodes* show the reticulations less well, but they are well marked on the operculum, which bears a long tapering filament, longer than the egg itself. They also occur just below the opercular rim, but fade away towards the fixed end. The general appearance of the eggs in the after-plume is shown in Pl. XL. fig. 15. They were found on the 27th July, 1908, and they seem to be laid throughout the summer.

There is no metamorphosis, the young leaving the egg-shell as a miniature of their parents.

II.—*Nirmus cameratus* Nitzsch.

This insect seems to have been first named by Nitzsch * in the year 1818, but with no description. Indeed, the animal is mentioned under the subgenus *Nirmus*, but is called *Philopterus cameratus*. It is figured and described, and a bibliography is given, in Denny's 'Monographia Anoplurorum Britanniæ' † under the name of *Nirmus cameratus*. Denny found it on the Red Grouse, the Black Grouse, "and I expect also on the Ptarmigan." Grube describes it in Middendorff's 'Siberian Travels' as existing on *Lagopus albus* and *L. alpinus*, thus confirming Denny's surmise.

It is mentioned in Giebel's article ‡ on the Halle Bird-lice, and described and figured in his great monograph 'Insecta

* Germar's 'Magazin der Entomologie,' Halle, iii. 1818, p. 291.
† London, 1842, p. 112.
‡ Zeitschr. ges. Naturwiss. xxviii. 1866, p. 370.

Epizoa.' Piaget, in his 'Les Pédiculines,' states his conviction, that *N. cameratus* is specifically identical with the *N. quadrulatus* of Nitzsch, from *Tetrao urogallus*, the Capercaillie. Kellogg in his Mallophaga ('Genera Insectorum') does not mention *N. cameratus* though he records *N. quadrulatus* from *T. urogallus*, *T. tetrix*, and *Lophophorus impeyanus*.

Nirmus is a more slender animal than *Goniodes*, and appears to be longer. It is rarer than the latter, though in the great majority of cases the two are found together. Most of what has been said above about *Goniodes* applies also to *Nirmus*, as their habits are very similar, except that *Nirmus* lives more on the skin and upon the base of the rachis of the feather than does *Goniodes*. It also seems to frequent the feathers under the wing, where *Goniodes* is seldom seen. Both species seem to wander all over the body; and though they seem rather more common upon the head, neck, and back, the old view that these biting-lice occur chiefly or exclusively on those parts of the body inaccessible to the beak was not borne out by our investigations (Pl. XLI. figs. 17 & 18).

The variation in size and in colour is very considerable. Dead specimens are not infrequently found, and these may be in some cases mistaken for cast skins. An average length is 3 mm., and an average width of the abdomen is 1·5 mm. The abdomen is the widest part. In no case did we find either *Goniodes* or *Nirmus* in the crop of the grouse, though, as we have just stated, they are fully exposed to being snapped up by the bird's beak if the bird cared to notice them. It is not known exactly how clean birds get infected: probably the Mallophaga simply crawl from one bird to another when the latter are contiguous, and the young birds are infected on the nest. There is evidence, however, that in some cases, probably rare ones, they cling to the grouse-fly and are by it transported to a new host.

In the summer of 1907 Mr. Fryer found some Mallophaga eggs. These were for the most part empty, but from one or two full ones he has succeeded in hatching out specimens of *Nirmus cameratus*. The eggs are white, and transparent when empty, just visible to the naked eye, 0·6 mm. in length, and about four times as long as they are broad. Each egg-case is beautifully reticulated, the areas between the reticulations being six-sided. At one end the egg has a cap which is pushed off when the young emerges. The eggs are laid between the barbules of the vanes or near the bases of the filo-plumes, and adhere to their supports by means of some sticky excretion (Pl. XLII. fig. 20).

The eggs appear to be laid throughout the summer; the first time we found them (some of them were empty) was on 2nd July, 1907, and we found others later in the season.

There is no metamorphosis; the young emerge from the egg-case as small miniatures of their parents. They seem to cast their skin several times, but the exact number of ecdyses is not known.

B. Diptera.—Flies.

(i.) Fam. **Hippoboscidæ.**

III.—*Ornithomyia lagopodis* Sharp.

Till recently it had been thought that the grouse-fly was the same species as the common bird-fly, *Ornithomyia avicularia* L.; but recently Mr. D. Sharp* has pointed out that it is a distinct species, which he has described, as follows, under the name of *O. lagopodis*:—It is "smaller than *O. avicularia*, and distinguished by its peculiar lurid blackish colour, without any trace of green even on its feet or legs; the rostrum is black, and the hairs of the body and appendages are shorter than in the better-known form; on each side of the thoracic pleuron, between the front and middle legs, there is a very large dark patch extending as far towards the middle as the base of the front coxa, and divided into two parts by an oblique pallid line. The head is considerably smaller and narrower than that of *O. avicularia*, and has beneath a very large area of smoky colour on each side. Mr. Collin has pointed out that the segments, or abscissæ, of the costa afford a good character; the relative lengths of the outer two being in *O. lagopodis* as 9–8, and in *O. avicularia* about 12 or $12\frac{1}{2}$–8. The bristles on the scutellum are usually more numerous, as well as larger, in *O. avicularia*." Recently a second species, *O. fringillina* Bezzi, has been separated off from the *O. avicularia*, so that we now have three species of *Ornithomyia* in this country, and probably more will be added as the group is further studied. Mr. Sharp thinks that the same species frequents the willow-grouse, *L. albus*, of Scandinavia.

The head and mouth-parts of this fly are very interesting. A ventral view shows, between the eyes, the short antennæ apparently of two joints, ending in four hairs, of which one is far longer than the others; other symmetrically arranged hairs are shown in Pl. XLIV. fig. 22. In the middle line is the proboscis; this consists of two lateral, movable, palp-like structures, each bearing hairs and terminating in a stout bristle. These structures are presumably the maxillary palps. Then there is a median very mobile structure, which is the sucking-tube; this moves in all planes, and may be protruded or withdrawn. Its mouth shows a somewhat plicated orifice, and behind it undoubtedly ends in a sucking pharynx. This median structure is probably homologous with the second maxillæ or the labium.

The feet of the grouse-fly are large but very beautiful. In Pl. XLIV. fig. 23, we show the outer surface of one of the feet, and the same figure shows part of the femur, the tibia, and the five joints of the tarsus, the fifth being by far the largest.

* Ent. Monthly Mag. II. ser. xviii. 1907, p. 58.

Fig. 24 shows the inner surface of the same, and on Pl. XLIII. will be found a coloured sketch of a foot seen obliquely. From these drawings, which have been prepared for me by Mr. Edwin Wilson of Cambridge, it will be seen that the large paired claws are double, and that whereas the distal limb of each claw is slender and very sharply pointed, the proximal limb is much stouter and ends bluntly. Between the claws is a median, feathered, process with hairs or bristles, and at the base of each double claw is a pulvillus covered with minute hairs. As fig. 24 shows, there are other processes for which I have no name. The arrangement of the hairs is faithfully given in the drawings.

We do not know the exact relations of the grouse-fly to the grouse. It is believed to suck its blood, and it will certainly bite human beings. For a time it seems to burrow amongst the feathers of the bird, and anyone handling grouse during the summer is likely to disturb a fly or two. They come buzzing out and are apt to crawl up one's sleeve by aid of the pair of great hooked claws on their feet. Altogether they have a sinister aspect, and to people who do not like flies they are very repellent. They occur freely in larders where freshly-killed grouse have been placed, and after a short time they leave their dead host and accumulate upon the windows.

The earliest month we have found the grouse-fly is in June, towards the end. The latest we have found up till the present time is September. Mrs. Duff Dunbar has taken them as late as October. Perhaps they are most plentiful in August.

The females seem to be commoner than the males, or, it may be, in August are more readily taken. Like other members of the Hippoboscidæ, which includes the horse-fly, forest-fly, and sheep-tick, the grouse-fly does not lay eggs, but the ovaries produce one large ovum at a time, and this passes into a dilated oviduct which acts as a uterus, and here the egg develops. After attaining a certain stage of development, the larva surrounds itself with a pupa-skin and is extruded. The chitin covering the larva hardens and blackens with exposure to the air, and forms the so-called pupa-case; in fact, one may almost say the young are hatched as pupæ. At no time is the larva exposed, though there is a larval stage free in the uterus wrapped first in the egg-shell and then in the pupa-case.

When first deposited the pupæ are light in colour and the case has not hardened. Those dissected out from a fly are shorter and more squat than the mature pupæ found on the ground (compare *a* and *b* in fig. 25, Pl. XLIV.), and the symmetrical ridges and elevations are much less well marked (Pl. XLIV. fig. 25, *d* & *c*). The mature pupæ are shown from above, from the side, and from the micropylar end in Pl. XLIV. fig. 25, *c*, *e*, & *f*, highly magnified. Between them they show well the six elevated and cross-barred ridges which radiate from the micropyle to the angles of the hexagonal micropylar area.

The pupæ were found during August and September. They

appear to be deposited amongst the feathers and are easily detached from them. The few we have found either dropped on some paper over which we were handling some birds, or lay loose at the bottom of the cardboard boxes in which grouse travel. Probably they take some eight or nine months before they give rise to the imagos, and the latter very likely disappear altogether from about October till June. Further research is needed to throw light on these questions.

Three specimens of *O. lagopodis*, all of them taken from one grouse, were themselves markedly infested with an ectoparasite, a species of mite. Here I refrain from quoting Dean Swift. The mite belongs to the genus *Canestrinia*, as my friend Mr. C. Warburton has kindly told me, and is probably a new species. The subfamily Canestrininæ are all parasitic upon insects, and are regarded as harmless. Our specimens existed in considerable numbers, clustered round the hinder end of the fly's abdomen on the ventral surface, with their proboscides plunged into its body. Many were laying eggs, and many cast-off cuticles were lying around. Eggs from which the larvæ had escaped presented a spindle-shaped outline; others contained ova in various stages of differentiation; others fully formed larvæ.

We have in no single case found a grouse-fly in the crop of a grouse, nor have we yet found any cestode larvæ or cysts in the bodies of the flies which we have cut into sections or dissected.

(ii.) Fam. Scatophagidæ=Scatomyzidæ.

IV.—*Scatophaga stercoraria* L.

This fly cannot be looked upon as an ectoparasite of the grouse, but it lays its eggs in grouse-droppings, and its maggots live on and in these dejecta. The maggots must therefore constantly be in close contact with and possibly eating the ova of the tape-worms which exist in such vast numbers in the grouse-droppings; and here we thought it was a profitable object to investigate for the cysticercus or second stage of the cestode. It should be mentioned that the droppings consist of two parts: (1) the dejecta from the intestine strictly speaking, and (2) the more fluid dejecta from the cæca. The latter pass last and lie like a cap upon the former. The fly-maggots are only found in numbers in the "cæcal" part of the dropping. Mr. Fryer first found them commonly at Fort Augustus in April. In June they were not so common, owing perhaps to the rain which washed the cæcal part of the droppings away. We examined a large number of the larvæ both by squashing them and cutting them into sections, but we found no trace of infection; in fact, here, in this most likely place, we again drew a blank. No specimen of *S. stercoraria* or of its larvæ has been found in the crop. This fly, which, as

stated above, we believe to be *S. stercoraria*, may eventually turn out to be a local variety.

The larva of the fly has the usual maggot-like shape, tapering from behind forward towards the mouth. Counting what appears to be the cephalic segment—but which in reality probably represents more than one segment, and which is thus conveniently called the "pseudo-cephalon" *—as one segment, there are thirteen in all, the usual number for Dipterous larvæ (Pl. XLV. fig. 26).

The cuticle is thin, the maggots are white. They bear numerous small spines which are especially conspicuous in a ring around the anterior end of each segment. These rings emphasize the segmentation of the larva.

The "pseudo-cephalon" is pointed, and varies in outline according to how much of the mouth and its sclerites are protruded or not. These sclerites are the most conspicuous structures in the larvæ; jet-black, they stand out against the white tissues of the maggot. There is a pair of hooks which apparently correspond with the single median mandibular sclerite of *Musca domestica* †. At the base of each of these is a dentate sclerite, and behind the mandibular sclerite articulates with the hypostomal sclerites. These latter are irregular longitudinal bars connected by a slight transverse plate on the ventral side. In *M. domestica* the salivary glands open into the pharynx just in front of this transverse piece. Posteriorly the hypostomal sclerites are very closely articulated, or perhaps even fused with the large lateral pharyngeal sclerite. This consists of a ventral plate, continuous with two lateral plates which are deeply notched, and in the house-fly the nerves and tracheæ which supply the pharynx enter through this notch. The two lateral plates are united anteriorly by a dorsal cross-piece. The whole of these sclerites are being continually pushed forward and retracted by a complicated series of muscles which have been carefully described in the case of *M. domestica* by Dr. C. Gordon Hewitt (Pl. XLV. fig. 27).

The mouth is bordered by tumid lips, above which the hook-like mandibular sclerites are pulled and pushed in and out. Dorsal to these again are two elevations which each bear two sensory papillæ; these correspond with the sensory tubercles of *M. domestica*, though the latter are not borne on an elevation.

The anus opens on the truncated thirteenth segment, well forward on the ventral surface; around it, symmetrically placed, are four anal papillæ, which assist in the movements of the maggot (Pl. XLVI. figs. 31 & 32).

The tracheal system opens on the flattened posterior end, about the centre. Ventral to the stigmata there are two or three pairs of low papillæ. Each stigma leads into a trachea, which almost immediately splits into a visceral branch (Pl. XLV. fig. 26) which bends down into the viscera and extends a little way in

* Henneguy, L. F., 'Les Insectes,' Paris, 1904.

† C. Gordon Hewitt, Quart. J. Micr. Sci. lii. 1908, p. 495.

front of the middle of the body. Before splitting in *M. domestica* the right and left main trunks are put into communication by a transverse trunk; if this exists in *S. stercoraria* it escaped our notice. The lateral trunks give off in each segment a dorsal and ventral twig. Anteriorly, in what appears to be the third segment (it is described as the fourth in the house-fly), there is a transverse commissure by means of which the right and left trunks are put into communication. In front two small twigs are given off from this transverse commissure which run to the pharynx. The main trunk is continued forward, and at the second segment (the third in the house-fly) it ends in a process like a little rake (Pl. XLV. figs. 26 & 27). This is due to the splitting up of the trachea into eight or nine little twigs, all in the same plane and all ending in a knob. The whole is called the anterior spiracle, and can be protruded from the body and retracted. Hewitt states that in the house-fly each of these knobs opens to the surface by a very minute pore.

C. Siphonaptera.—Fleas.

(i.) Fam. **Pulicidæ.**

V.—*Ceratophyllus gallinulæ* Dale*.

Synonym: *Ceratophyllus* (*Trichopsylla*) *newsteadi*† Rothsch.

I am indebted to my friend Mr. N. C. Rothschild for identifying this flea, which is here recorded for the first time from the grouse. It is a well-known bird-flea, having been found in the nest of the hawfinch, *Coccothraustes vulgaris*, in that of the dipper, *Cinclus aquaticus*, in that of the blackbird, *Turdus merula*, the moor-hen, *Gallinula chloropus* L., and others. In the thousands of grouse which have passed through our hands we have found but one or two specimens of this flea, all in 1906, and we have never found a single specimen in the crop. Hence, although the dog-flea, *Pulex serraticeps* P. Gerv., is said to be the intermediate host of the dog tape-worm, *Dipylidium caninum*, it seems hardly possible that the *C. gallinulæ* could play any part in the life-history of the grouse tape-worms. In identifying a flea almost every hair tells, and as *C. gallinulæ* has not been accurately figured before, I take this opportunity of figuring it in both sexes.

VI.—*Ceratophyllus garei* Rothsch.

This second species of flea was found in a grouse in 1907; we only took one or two specimens. It is recorded by Evans‡ from the nest of the water-vole, of the lapwing, *Vanellus vanellus*, and of the ring-dove, *Columba palumbus*. Rothschild§ has found it

* N. C. Rothschild, Ent. Monthly Mag. II. ser. xiv. 1903, p. 145.
† Ent. Rec. xiii. 1901, p. 284.
‡ Ann. Scott. Nat. Hist. 1906, p. 163.
§ Ent. Monthly Mag. II. ser. xiii. 1902, p. 225.

in the nest of a water-hen, *Gallinula chloropus*, and he records it as having been taken from *Mustela erminea*, *M. vulgaris*, *Sorex vulgaris*, *Microtus glareolus* and *M. amphibius*, and from hedge-clippings.

ARACHNIDA.

Acarina.—Mites and Ticks.

(i.) Fam. Ixodidæ.—Ticks.

VII.—*Ixodes ricinus* (L.).

This is one of the commonest and one of the oldest-known ticks of Europe. In the British Isles it usually occurs on hunting-dogs and is sometimes called the "dog-tick"; the adult stage is especially frequent on sheep, goats, and oxen, less common on horses, dogs, and men. Mr. William Evans *, of Morningside Park, Edinburgh, tells me that he has not found this species on dogs—in his district the "dog-tick" being *Ixodes hexagonus* Leach, var. *inchoatus* Neum. On the other hand, the larvæ and the nymphs are common enough on birds, lizards, and small mammals—in fact, on animals which live among and brush against grass or heather. It is only in the nymph and larva state that we found these ticks on the grouse. On each of the infested birds the specimens were fixed on the chin or around the eyelids—in fact, in such positions as the grouse cannot reach with its beak. In parts of Ross-shire, especially in certain woods, these ticks swarm in enormous numbers, and the keepers assure us that they kill large numbers of young blackgame. Hence there is nothing remarkable in finding this species from time to time on the grouse, where its presence must be regarded as accidental. The larval stages emerge from the eggs and probably crawl on to the heather, and thence on to the grouse or other animals which come in contact with the vegetation. We have found both larvæ and nymphs amongst the feathers, but in small quantities and on rare occasions. We have never found it in the crop, and it can hardly play any part in infecting the bird with tape-worms.

Ixodes ricinus, or the "castor-bean tick," as it is called in America, is common in many parts of the world. It is reported from sheep, goats, cattle, horses, deer, dogs, cats, foxes, ferrets, hedgehogs, hares, rabbits, bats, birds, and man. This tick occurs most frequently during the spring and early summer, but can be found in lesser numbers up till September and October, possibly later.

Severe epizootics amongst fowl of spirillosis and of another obscure but very often fatal disease have been described by

* Ann. Scott. Nat. Hist. 1907, p. 35.

Balfour* in the Sudan. The spirochæte, probably *Spirochæta gallinarum*, which causes the first-named disease is transferred from one fowl to another by a tick, *Argas persicus*. The second, and as yet rather obscure, disease is recognised by the natives and by them associated with the presence of the *Argas*. We have found no traces of such disease in grouse, and the recorded number of ticks taken in the grouse is, except locally, so small that they can hardly play any part in grouse-disease.

(ii.) Fam. Tyroglyphidæ.

VIII.—*Aleurobius farinæ* (de Geer).

Synonym : *Tyroglyphus farinæ* Gerv.

Mr. C. Warburton has kindly identified for us a small mite which was found in considerable numbers on several birds and at varying times of the year. Whilst very common at Easter time, they were less abundant in July. *Aleurobius farinæ*, sometimes known as the flour-mite, occurs in great numbers on all sorts of organic material—grain, straw, hay, tobacco, flour, cheese, dead bodies, etc., etc. At times workmen handling corn, cats, horses, etc., have suffered much cutaneous irritation and eruption from the attacks of this mite. There seems no doubt as to the species of this mite, but the authorities on these animals express surprise that they should occur so commonly on the grouse. Our specimens, some of which were taken on freshly killed grouse, contained some red substance in the stomach, probably some blood from the bird. There seems at present little reason to incriminate this mite as the carrier of the tape-worm cyst. They were, however, found by Mr. Fryer on a large majority of birds which were especially searched with the view of finding mites.

(iii.) Fam. Gamasidæ.

IX.—*Gamasus coleoptratorum* (L.).

We have also taken this common, fawn-coloured mite off the feathers of a grouse. It is usually found on beetles, but winters under stones, and it is said to soon die if removed from the beetle or from under the stone where they hide, unless they are kept moist. The beetles they favour are usually burrowers in the damp ground or under cow-dung. They probably passed on to the grouse from under stones.

* Brit. Med. Journ., 9th November 1907, No. 2445, p. 1330.

General Discussion on the Relations of Ectoparasites to the Endoparasites of the Grouse.

We have in the alimentary canal three species of tape-worm, two of the genus *Davainea* and one of the genus *Hymenolepis*. We know that tape-worms, with perhaps the exception of one species, pass through two distinct and different animals known as hosts. In one animal it lives as an adult, in the other as a larva. The larval host is always, sooner or later, eaten by the host of the adult, and then the larval tape-worm or cyst grows into the adult tape-worm. It was with the hope of discovering the second or larval host of the grouse cestodes that we began a laborious research on the insects and arachnids which infest the grouse. Unfortunately, little or nothing is known about the life-history of any species of either *Davainea* or *Hymenolepis*. The larval or cystic stages of the former have in some few cases been said to occur in insects and in molluscs; the larva of the latter is thought to live in an insect or a myriapod, or perhaps even more likely some "water-flea" or other fresh-water crustacean.

With regard to these possible second hosts. We have never found a myriopod in the crop of a grouse, and so far we have not found any crustacea—though it must not be forgotten that these are probably so small as to escape notice. We have found one species of slug in the crop of a Staffordshire grouse, which Mr. W. E. Collinge has kindly identified for us as *Arion empiricorum* Férussac, a species of slug which is common on the Staffordshire grouse-moors. He tells me that the slug undoubtedly belongs to the genus *Arion*, and almost certainly to Férussac's species *A. empiricorum*, a name J. W. Taylor, in his 'Monograph of Land and Fresh-water Mollusca of the British Isles' *, includes among the synonyms of *Arion ater* (L.). The well-known difficulty of identifying slugs which have been preserved and which have lost their colour accounts for the slight doubt that exists. *Arion empiricorum* is very voracious and practically omnivorous; it will eat almost anything, especially decaying animal and vegetable matter, fungi, paper, weak and injured worms and slugs, and—what is interesting from the point of view of the grouse tape-worms and round-worms—it devours the dejecta of other animals. It prefers the shady places in moors and fields, and emerges into the open only at dusk or when the day is cloudy or overcast. The following parasites which may give rise to adult forms in the grouse have been found in *A. empiricorum*:—

Trematoda (Flukes):

(1) *Cercariacum limacis* Duj.†
(2) *Cercaria trigonocerca* Dies.‡

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* Leeds, part xi. p. 167. † Dujardin, Hist. nat. des Helm. p. 472.
‡ Leuckart, Paras. d. Menschen, 2nd edit. ii. p. 86.

Cestoda (Tape-worms):

(1) *Cysticercus arionis* v. Sieb.*
(2) *Cysticercus tæniæ arionis* v. Sieb.†

Nematoda (Round-worms):

(1) *Leptodera angiostoma* Duj. ‡
(2) *Leptodera appendiculata* Schneider §.
(3) *Nematodum limacis atra* v. Sieb. ‖
(4) *Pelodytes hermaphroditus*, Schneider ¶.

We have cut one of these slugs into sections, and have sought diligently through them for cysts of tape-worms, but have found none. This absence of infection, combined with the great rarity of the slug in the grouse's crop, seems to show that *A. empiricorum* is not the second or larval host of the grouse cestodes.

Dr. Wilson and Mr. Fryer "tow-netted" some of the moor streams in April 1907, and found a certain number of the nauplius larva, probably of *Cyclops*, and a certain but small number of adult *Cyclops*. The numbers were, however, meagre, and tow-nettings later in the summer yielded an even more unsatisfactory "bag." None of the crustacea when examined microscopically showed any cysts, and as they were few in number and quite cyst-less, it seems improbable that the source of the tape-worm infection lies here.

Mr. D. J. Scourfield, who kindly looked through some of these tow-nettings, tells me he found the following species of Entomostraca:—

CLADOCERA.

Chydorus sphæricus O. F. M., the most abundant form.
Alonella nana (Baird, Norman & Brady), frequent.
Alonella excisa (Fisch.), frequent.
Acantholeberis curvirostris (O. F. M.), a fair number, with some cast ephippia.

COPEPODA.

Cyclops nanus Sars, a few.
Cyclops languidus Sars, a single specimen only seen.
Cyclops vernalis Fisch., again only one specimen was seen.

I subjoin three more lists of tow-netted freshwater Entomostraca from three different lochs. These were collected and identified by Mr. Wm. Evans, who has kindly put them at my disposal, and they clearly indicate the sort of surface fauna which may be obtained from the lochs on the Scotch moors in early autumn.

* Von Siebold, Zeitschr. wiss. Zool. ii. 1850, p. 202.
† Krabbe, Nye Bidrag, p. 5; and Villot, Ann. Sci. nat. 6th ser. xv. 1883.
‡ Schneider's Monograph, p. 157.
§ Schneider's Monograph, p. 159.
‖ Schweiz. Zeitschr. Med. 1848.
¶ Zeitschr. wiss. Zool. x. p. 176.

List I.

From Loch Rusky, a moorland loch a few miles from Callander, which was tow-netted on the 16th September, 1906.

CLADOCERA.

Simosa vitula (O. F. M.).
Eurycercus lamellatus (O. F. M.).
Alonopsis elongata G. O. Sars.
Alona affinis Leydig.
Chydorus sphæricus (O. F. M.).

OSTRACODA.

Cyclocypris globosa (G. O. Sars).
Pionocypris vidua (O. F. M.).
Notodromus monacha (O. F. M.)
Candona candida (O. F. M.).

COPEPODA.

Moraria brevipes (G. O. Sars).
Cyclops viridis (Jurine).
Cyclops annulicornis Koch.
Cyclops serrulatus Fischer.

List II.

From Peat-pools on grouse-moors on Ben Ledi, in South-west Perthshire, Sept. 1908.

CLADOCERA.

Chydorus sphæricus (O. F. M.), very abundant.

OSTRACODA.

Herpetocypris tumefacta (B. & R.).
Cypridopsis villosa (Jur.).
Potamocypris fulva (Brady).
Candona candida (O. F. M.).

COPEPODA.

Attheyella zschokkei (Schm.).
Attheyella cuspidata (Schm.).
Cyclops vernalis Fisch.

List III.

From Loch-a-Chroin, north of Callander.

CLADOCERA.

Bosmina longirostris (O. F. M.).
Acroperus harpæ Baird.
Alonopsis elongata (G. O. Sars).
Alona quadrangularis (O. F. M.).
Alonella excisa (Fisch.)
Chydorus sphæricus (O. F. M.).

OSTRACODA.

Cyclocypris serena (Koch).

COPEPODA.

Diaptomus gracilis (G. O. Sars).
Cyclops viridis (Jur.).
Cyclops serrulatus Fisch.

Also the common freshwater Amphipod, *Gammarus pulex* (De Geer).

A complete list, so far as was known at that time, of the Entomostraca of the Highlands and of the Lowlands could be extracted from the very useful Synopses published by Scourfield in the Journal of the Quekett Microscopical Club during the years 1903 and 1904.

In none of the species examined have we yet succeeded in finding any cysts.

We have thus with some degree of probability shut out as the second or larval host of the tape-worms—at any rate for the present—the ectoparasites of the grouse, the myriapoda and the slugs or snails, and the fresh-water crustacea, and this on the grounds (1) that on examination none of them reveals a cyst, and (2) that these animals are either not eaten by the bird, or so rarely eaten and in quantities so small as to render it highly improbable that any of these invertebrates could account for the almost constant presence of the cestodes in large numbers in the grouse.

Two rather striking facts seem to point to the normal insect food of the grouse, which it picks up on the moor, as the more probable source of the tape-worms. One is, that two of the artificially reared grouse at Frimley, which died during the early autumn of 1907, were carefully searched for tape-worms; but neither *Davainea* nor *Hymenolepis* was found. The second fact is, that the young grouse often contain fully grown *Davainea* before they are three weeks old. They must certainly have swallowed the second host when very young, perhaps even the day they were hatched, or the worm would not have had time to grow. Hence our best chance of finding this second host is to examine the crop-contents of the very young birds, and to do this we must have a moor at our disposal, and leave to kill as many young birds as we may want.

I have been assured over and over again by sportsmen and gamekeepers that the grouse eats no insects, but this is far from the truth.

Although the observations on the animal food of grouse are still incomplete, enough has been done to show that it is fairly abundant and very varied.*

From the crop of a single bird I have taken six larvæ of

* A fuller report on the insects found in the grouse-crop is given by Mr. J. C. F. Fryer in the Interim Report of the Grouse Disease Inquiry, published in August 1908. The following two paragraphs relate to some observations of my own, made in 1905 and 1906.

Tenthredinidæ (saw-flies), eight caterpillars of a Geometrid moth, one caterpillar of a smaller moth, two small Tineid moths, a number of immature Homopterous insects resembling the "frog" or "cuckoo-spit," a fly, possibly a *Leptis*, two specimens of the family Aphidæ (plant-lice), one small spider, and the remains of four specimens of the slug *Arion empiricorum* Fér. The gizzard of the same grouse contained, in a more broken up condition and consequently more difficult to identify, two or three dozen larvæ of saw-flies and moths, some young Homopterous insects, and the pupæ of two Muscid flies.

The segments of the grouse tape-worms containing the ripe eggs pass away with its dejecta and get on the ground or on to the heather and other plants, or into water. The eggs of the two species of *Davainea* are believed to develop into the cestode larva inside the body of an insect or a land mollusc. They are excessively minute, and lying as they do in millions on the heather, may be readily consumed by the leaf-eating caterpillars and other insect larvæ which live on the moors. Doubtless many are eaten by the grouse themselves, but they are digested and come to nothing. As we have said above, a tape-worm must have a second or intermediate host, and its larval stage must be passed inside an animal quite distinct from that which harbours the adult worm. To get at and eat the eggs seems to me an easier matter for caterpillars and other insect larvæ or for slugs than it is for the ectoparasites, which as a rule are not very likely to come across the dejecta of their host. For this reason, in looking for the larval tape-worm, we are now searching the insect larvæ and the slugs eaten so eagerly by the grouse. A common food of grouse is the head of certain species of rush. *Juncus articulatus* v. *lamprocarpus*, *J. squarrosus*, and *J. effusus* v. *conglomeratus* are all frequently eaten. There is a very minute moth the larvæ of which live in curious, white, papery cases inserted into each twig of the rush-head which they eat. When the rush is in its turn eaten by the grouse, the larvæ of the moth pass into the alimentary canal of the bird and are there digested. It has not been possible to finally determine the species of the moth, but I think it is *Coleophora cæspititiella**, for this species frequents many species of rush; whereas the *C. glaucicolella*, the other inland species, is most partial to *Juncus glaucus*. The former is usually fully out by the middle of June and lingers on till the middle of July; the last-named moth issues about the middle of July, and flies for four weeks. The case is whitish, semi-transparent, and with brown specks; it is found when the larva is no longer young, but not at any very fixed time. At first its outer end is closed. The larva often leaves the case, burrowing into the rush-head for food, and at times fails to refind it. Before pupating, the outer or anal end of the case is opened and the case strengthened by a glandular excretion. These larvæ should be searched for cysts.

* J. H. Wood, Ent. Mag. II. Ser. iii. (xxviii.) 1892.

EXPLANATION OF THE PLATES.

List of Abbreviations.

a., anus.
ant., antennæ.
a.p., chitinous rod supporting upper movable lip.
a.s., anterior spiracle.
c., coxa.
cr. in fig. 12, & c. in fig. 16, crop.
dg. in fig. 27 & ds. in fig. 28, dental sclerite.
dg. & d.gl., ducts of oval glands.
e., eye.
emp., empodium.
f., femur.
f.b., fat-bodies.
gl. & glds., oval gland.
h.l., "moustache" lip.
h.s., hypostomal sclerite.
int., intestine.
1st lg., 1st leg.
lu., upper lip.
lyr., lyriform organ.
m., mouth.
m.a., micropylar area.
mb., rectum.
md., mandible.
mi., micropyle.
m.s., mandibular sclerite.
m.t., Malpighian tubules.
1 max. & 1 mx., 1st maxilla.
2 max. & 2 mx., 2nd maxilla.
mx.p., maxillary palp.
œ., œsophagus.
ov., ovary.
p. & ped., pulvillus.
prob., proboscis.
p.s., posterior spiracle.
ph.s., pharyngeal sclerite.
r.gld., rectal glands.
sp., spines.
st. in fig. 9, crop; in figs. 29 & 30, st., sensory papillæ.
sti., stigma or spiracle.
sto., stomach.
t.c., transverse commissure.
ta., tarsus.
ti., tibia.
tr., trochanter.
u.l., upper lip.
v.t., visceral trachea.

Plate XXXV.

Fig. 1. *Goniodes tetraonis* Denny, male seen from above. The legs are shown on the left side only. The forked character of the antennæ, the upper lip and the lyriform organ are well shown in the head and the male genital plates in the abdomen.

2. *Goniodes tetraonis* Denny, female seen from above. Note the different shape of the head and of the outline of the body. The legs are not shown.

3. The same seen from below, showing the upper lip, the mandibles, the lyriform organ, and the legs.

Plate XXXVI.

Fig. 4. Ventral view of head of male *G. tetraonis*, showing the forked antennæ, the mandibles, the pores in the chitin under the hairs, the muscles running to the upper lip, the eyes, the lyriform organ, and the ducts of the oval gland.

5. View of mouth-parts showing the "upper lip" *u.l.*, the moustache lip *h.l.*, the mandibles *md.*, the first maxillæ 1 *max.*, the second maxillæ 2 *max.*, the ducts of paired glands *d.gl.* and the lyriform organ *lyr.*, and the chitinous bar supporting the upper lip *a.p.*; *glds.*, the oval gland.

Plate XXXVII.

Fig. 6. View of the ventral surface of right mandible showing the complex nature of its articulation.

7. View of the 1st and 2nd maxillæ and of the mouth, the mandibles having been removed. The glands with their paired ducts uniting in the middle line to open by a median duct into the pharynx, in the centre of the lyriform sclerite. *m.* mouth.

Plate XXXVIII.

Fig. 8. View of the glands and the lyriform organ, showing the opening of the duct.

9. Ventral view of the complex, male, external reproductive apparatus, formed by various sclerites in the wall of the invaginated genital pouch. The posterior angle of the crop *st.* is shown.

Plate XXXIX.

Fig. 10. A ventral view of the right mesothoracic leg, showing the joints, claws, and *p.* the pulvillus, *c.* coxa, *f.* femur, *ta.* tarsus, *ti.* tibia, *tr.* trochanter.

11. View of the tracheal system of a female, showing the stigmata, *sti.*

PLATE XL.

Fig. 12. Alimentary canal of *G. tetraonis* dissected out: *oe.* œsophagus, *cr.* crop, *sto.* stomach, *m.t.* Malpighian tubules, *mb.* intestine, *r.gld.* rectal glands.
13. Some of the crop-contents of *G. tetraonis*, pressed out. It consists of feathers in various stages of disintegration.
14. Egg of *Menopon pallescens* Nitzsch. Under pressure the operculum has come off and the ovum is squeezing its way out.
15. Four eggs of *Goniodes tetraonis*, attached to the base of an after-plume, between it and the shaft of the plume of a feather from the flank. In one of them the operculum has fallen off.

PLATE XLI.

Fig. 16. Optical section of abdomen of *G. tetraonis*, showing *a.* anus, *c.* crop, *f.b.* fat-bodies, *int.* intestine, *r.glds.* rectal glands, *ov.* ovary.
17. *Nirmus cameratus* Nitzsch. Dorsal view of female.
18. Ventral view of the same.

PLATE XLII.

Fig. 19. Ventral view of head of *Nirmus cameratus*, showing mouth-parts, antennæ, eyes, position of anterior legs.
20. Eggs of *Nirmus cameratus* on the feathers of a young grouse approximately three weeks old. A. Very slightly magnified; three eggs on one of the wing-coverts. B. Magnified about eight times on a downy plume. C. Very highly magnified to show the reticulations.

PLATE XLIII.

Fig. 21. *Ornithomyia lagopodis* Sharp. A. dorsal view, B. ventral view, C. dorso-lateral view of foot.

PLATE XLIV.

Fig. 22. A ventral view of the anterior edge of the head of *O. lagopodis* and the mouth-parts. *Ant.* antennæ, *e.* eyes, *mxp.* maxillary palp, *prob.* proboscis. A still more enlarged view of the orifice of the proboscis is shown to the right.
23. A figure of part of the femur, *f.*, the tibia, *ti.*, the tarsus, *ta.*, and the foot of *O. lagopodis*.
24. The same, more highly magnified, from the inner or under surface. *emp.* empodium, *ped.* pulvillus.
25. Five sketches of the pupa of *O. lagopodis*. A. Life-size figure of the mature pupa; B. the same of an immature pupa dissected out of a fly; C. mature pupa-case magnified and seen from the micropyle end; D. a similar view of the immature pupa; E. mature pupa-case seen from above; F. the same seen from the side. *m.* micropyle, *m.a.* micropylar area.

PLATE XLV.

Fig. 26. The larva of *Scatophaga stercoraria* L. A. Life-size: B. magnified. *a.s.* anterior spiracle, *p.s.* posterior spiracle, *h.s.* hypostomal sclerite, *m.s.* mandibular sclerite, *ph.s.* pharyngeal sclerite, *v.t.* visceral trachea, *t.c.* transverse commissure.
27. Enlarged view of oral and pharyngeal sclerites, lettering as in fig. 26. *d.g.*, dental sclerite.

PLATE XLVI.

Fig. 28. Enlarged view of head of the maggot, showing *a.s.* anterior spiracles, spines, more pronounced at the anterior end of each segment, *m.* mouth, *f.b.* fat-body; other lettering as in fig. 26.
29. Lateral view of mouth of the maggot, showing sensory papillæ. Magnified.
30. Dorsal view of the head of the maggot, showing the anterior spiracles protruded. Magnified.
31. Dorsal view of posterior end of maggot, showing *p.s.* posterior spiracles, the split tracheal main trunks and papillæ. Magnified.
32. Lateral view of the same, showing *a.* the anus. The specimen was slightly compressed and the posterior spiracles were a little displaced and both brought into view.

PLATE XLVII.

Fig. 33. Side view of male specimen of *Ceratophyllus gallinulæ* Dale.
34. Side view of female specimen of the same drawn to scale.